

water than the individual fish, whereas, at night, the majority of fish observed were at shallower depths.

CONCLUSIONS

The technique described above for determining spatial and thermal distribution of fish near heated discharges has been found to be useful, although there are limitations and areas for refinement. The effectiveness of the echo sounder near the surface and in shallow water is limited because of the small sampling volume in the sonic cone near the transducer and uncertainty as to the effect of the proximity of the towed vehicle and vessel on the behavior of the fish. Also, an echogram recorder with a shorter range (0-50 ft) would be more useful for working in shallow water.

Fish near the surface may be detected with side scanning sonar equipment, but side scanning methods are difficult to quantify even under ideal conditions (Smith, 1970). These methods are impractical in the presence of a thermal gradient, due to resultant scattering effects. Detection of fish near the surface could also be accomplished with bottom mounted transducers facing vertically upward. Upward-looking acoustic systems with electronics located in buoys are being developed for sockeye salmon assessment in Alaska (Hartt et al., 1972). Fixed location systems have several disadvantages, including small sample size, lack of continuity between stations, and lack of direct correlation with thermal mapping. However, the use of bottom-mounted systems in critical locations to supplement the surveys with the towed system and thermal mapping would provide information on the distribution of fish near the surface, as well as providing continuity between surveys.

The species composition of fish targets is not derived directly from the acoustic data and must be obtained independently from net samples. Size composition, which may also be obtained from analysis of echo amplitudes (Thorne, 1972). However, a large number of observations are required to extract size information from echo amplitudes. Thus, prac-

tical application of acoustic techniques for size determination must await completion of computer processing systems for this purpose.

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LITERATURE CITED

- HARTT, A. C., M. B. DELL, G. E. LORD, AND D. E. ROGERS. 1972. High Seas Salmon Studies, p. 8-11. In 1971 Research in Fisheries, College of Fisheries, Univ. of Washington, Contrib. 133.
- MARKELLO, S. J., AND J. F. STORR. 1971. The use of the Ross Fine Line Recording Fathometer as a tool for measuring fish distribution in Lake Ontario. Presented 14th Conf. Great Lakes Res. Toronto (abstract).
- MOOSE, P. H., AND J. E. EHRENBURG. 1971. An expression for the variance of abundance estimates using a fish echo integrator. J. Fish. Res. Bd. Canada 28(9): 1293-1301.
- ROMBERG, G. P., W. PREPECHIAL, AND D. M. NELSON. 1971. Thermal plume measurements. Proc. 14th Conf. Great Lakes Res., p. 625-639.
- SMITH, P. E. 1970. The horizontal dimensions and abundance of fish schools in the upper mixed layer as measured by sonar. Proc. Int. Symposium on Biological Sound Scattering in the Ocean, March 31-April 2, 1970, p. 563-608.
- THORNE, R. E. 1972. Hydroacoustic assessment of limnetic-feeding fishes. In Proceedings—Research on Coniferous Forest Ecosystems—A Symposium, 6 p., Pacific Northwest Forest and Range Exp. Sta., Portland, Oregon.

Sample Size in Sport Fishery Surveys¹

CHARLES W. CAILLOUET, JR.
Gulf Coastal Fisheries Center
National Marine Fisheries Service
Galveston, Texas 77550

JAMES B. HIGMAN
Rosenstiel School of Marine and Atmospheric
Science, University of Miami
Miami, Florida 33149

ABSTRACT

Described is a method for estimating sample size (n) in sport fishery surveys in which the sample mean square residual ($s_{e,r}^2$) for the regression

¹ Sci. Con. No. 1608, University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, Florida 33149.

through the origin) of catch (C) on effort (F) is related to the sample mean catch rate (b , the slope of the regression of C on F).

Catch rate is usually expressed as number of fish per unit effort in sport fishery surveys. Calculation of mean catch rate (for a given species, sampling location, and period of time) is equivalent to fitting a straight regression line through data points representing measurements of catch, C , and effort F , and through the origin (0, 0), according to the following relationship:

$$C = \beta F + \epsilon$$

When $F = 0$, it follows that $C = 0$, but with $F > 0$, C may be either greater than or equal to zero. The mean catch rate, β , is estimated by the sample slope, b , of the fitted regression line. Snedecor and Cochran (1967) present three different estimators of the slope of such lines. Which of these three estimators is appropriate depends upon the distribution of the residual, ϵ . Grosslein (1962) has discussed two of the estimators in his analysis of sport fishery data.

The sample mean square residual, $s_{e,r}^2$, for the regression of C on F is related to the sample mean catch rate by a simple power function (see examples, Table 1),

$$s_{e,r}^2 = ab^z$$

in which "a" is essentially a scaling factor dependent upon the units of measurement of C and F , and "z" is an index of aggregation characteristic of the population (Taylor, 1961). Both "a" and "z" are determined empirically. Methods for calculation of such power functions are discussed by Piennar and Thomson (1969) and Glass (1969). This dependence of the mean square residual on the mean catch rate presents a problem in application of the sample size formula,

$$n = t_{\alpha}^2 s_{e,r}^2 L^{-2}$$

in which t_{α} is "Student's t" at the percentage confidence level equal to $100(1 - \alpha)$, and L is the "allowable error" (Snedecor and Cochran, 1967). Since the mean square residual is dependent upon the mean catch rate, sample size is also dependent upon the mean catch rate. To reduce the effect of such dependence of sample size on the mean catch rate, the "allowable error" can be expressed as a proportion, p , of the mean catch rate, b (Grosslein, 1962), instead of a chosen constant. Thus L becomes dependent upon b ,

$$L = pb$$

When ab^z is substituted for $s_{e,r}^2$, and pb is

TABLE 1.—Empirical regressions of $Y (= \log_{10} s_{e,r}^2)$ on $X (= \log_{10} b)$ for nine combinations of three species and three fishermen-types from the sport fishery at Flamingo, Everglades National Park, Florida¹

	Intercept, $\log_{10} a$	Slope, z	Number of months	Correlation coefficient, r	Standard deviation from regression
Cray snapper (<i>Lutjanus griseus</i>)					
Weekend fishermen	0.3492	1.4416	109	0.91	0.2370
Charter fishermen	0.1747	1.6457	85	0.90	0.2746
Weekday fishermen	0.3860	1.6241	97	0.88	0.2941
Spotted seatrout (<i>Cynoscion nebulosus</i>)					
Weekend fishermen	0.4479	1.6781	109	0.90	0.2329
Charter fishermen	0.2475	1.8540	85	0.92	0.2921
Weekday fishermen	0.4800	1.8748	97	0.89	0.2769
Red drum (<i>Sciaenops ocellata</i>)					
Weekend fishermen	0.4535	1.6353	108	0.93	0.2827
Charter fishermen	0.2764	1.6995	85	0.97	0.2704
Weekday fishermen	0.4207	1.6964	91	0.96	0.2559

¹ b and $s_{e,r}^2$ were monthly values calculated from fishing party interviews as follows:

$$b = \left[\sum_{i=1}^n (C_i/F_i) \right] / n$$

$$s_{e,r}^2 = \left\{ \sum_{i=1}^n (C_i/F_i)^2 - \left[\sum_{i=1}^n (C_i/F_i) \right]^2 / n \right\} / (n-1)$$

in which C_i was the catch (number of individuals) of a given species by the i th fishing party, F_i was the number of fisherman-hours of effort by the i th fishing party, and n was the number of fishing parties interviewed in a given month. The charter fishermen category was comprised of fishermen who fished from chartered vessels, on either weekdays or weekends. The weekday and weekend fishermen categories were comprised of fishermen who did not fish from chartered vessels. Only non-zero values of b and $s_{e,r}^2$ were used in the calculations.

substituted for L , the sample size formula becomes,

$$n = t_{\alpha}^2 ab^2 p^{-2} b^{-2}$$

For $z > 2$, the estimated sample size would increase with increase in the mean catch rate, and for $0 < z < 2$, sample size would decrease with increase in mean catch rate. This deviation of z from 2 has pronounced effect on sample size, especially for $0 < b < 1$. For $z = 2$, sample size would not depend on the mean catch rate.

A further simplification can be obtained if the standard deviation from regression, $s_{c.f.}$, is related to the mean catch rate, b , as a direct proportion (see Snedecor and Cochran, 1967, for fitting straight lines through the origin), in which the coefficient of proportion "d" is determined empirically,

$$s_{c.f.} = db$$

In this case, $d^2 b^2$, is substituted for $s_{c.f.}^2$ in the sample size formula,

$$n = t_{\alpha}^2 d^2 b^2 p^{-2} b^{-2},$$

which reduces to

$$n = t_{\alpha}^2 d^2 p^{-2},$$

in which sample size does not depend upon the mean catch rate.

Values of α and p can be manipulated to estimate sample sizes, allowing measurement of mean catch rate to the desired levels of confidence and relative precision.

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LITERATURE CITED

- GLASS, N. R. 1969. Discussion of calculation of power function with special reference to respiratory metabolism in fish. *J. Fish. Res. Bd. Canada* 26: 2643-2650.
- GROSSLEIN, M. D. 1962. Estimation of angler harvest on Oneida Lake, New York. Ph. D. Dissertation, Cornell University, Ithaca, New York. 296 p.
- PIENAAR, L. V., AND J. A. THOMSON. 1969. Allo-

- metric weight-length regression model. *J. Fish. Res. Bd. Canada* 26: 123-131.
- SNEDECOR, G. W., AND W. G. COCHRAN. 1967. *Statistical methods*. 6th ed. The Iowa State University Press, Ames, Iowa. 593 p.
- TAYLOR, L. R. 1961. Aggregation, variance and the mean. *Nature* 189 (4766): 732-735.

A Versatile and Inexpensive Variable Voltage Pulsator for Electrofishing

E. N. SMITH, B. J. VENABLES,
AND O. T. LIND

Department of Biology and The Institute
of Environmental Studies, Baylor University,
Waco, Texas 76703

This presents a circuit description and parts list for an easily assembled, inexpensive variable voltage pulsator for electrofishing. Pulsed direct current is one of the most effective techniques for the capture of centrarchid fishes (Lagler, 1968). A variable voltage pulsator (VVP) connected between an AC generator and the electrodes rectifies the AC voltage and produces a pulsed DC of variable voltage and pulse rate. The VVP has been an expensive part of earlier electrofishing rigs costing from \$300-\$400 (Stubbs, 1965). We have constructed an easily assembled, versatile, variable voltage pulsator for about \$100.

This VVP has the following modes of operation and characteristics: (1) AC 0-150V, 10 amps, (2) half-wave DC 0-150V, 10 amps, 60 cps. (3) pulsed DC 0-150V, 10 amps, 15, 30, or 60 cps. Automatic short circuit protection is included.

CIRCUIT DESCRIPTION

Power from the AC generator passes through the on-off switch (S1) and line fuses (F1 and F2) to the variable autotransformer (T1) and fan fuse (F3) (Fig. 1). Power from F3 operates the small shaded pole axial fan used to cool the power resistor (R1) and the heat sink on which are mounted diodes D2, D3, and D4. The variable output voltage from the autotransformer passes through the electrode fuse (F4) and current meter (M1) to D3, D4, and the AC position of the function switch (S3). The AC generator output line voltage

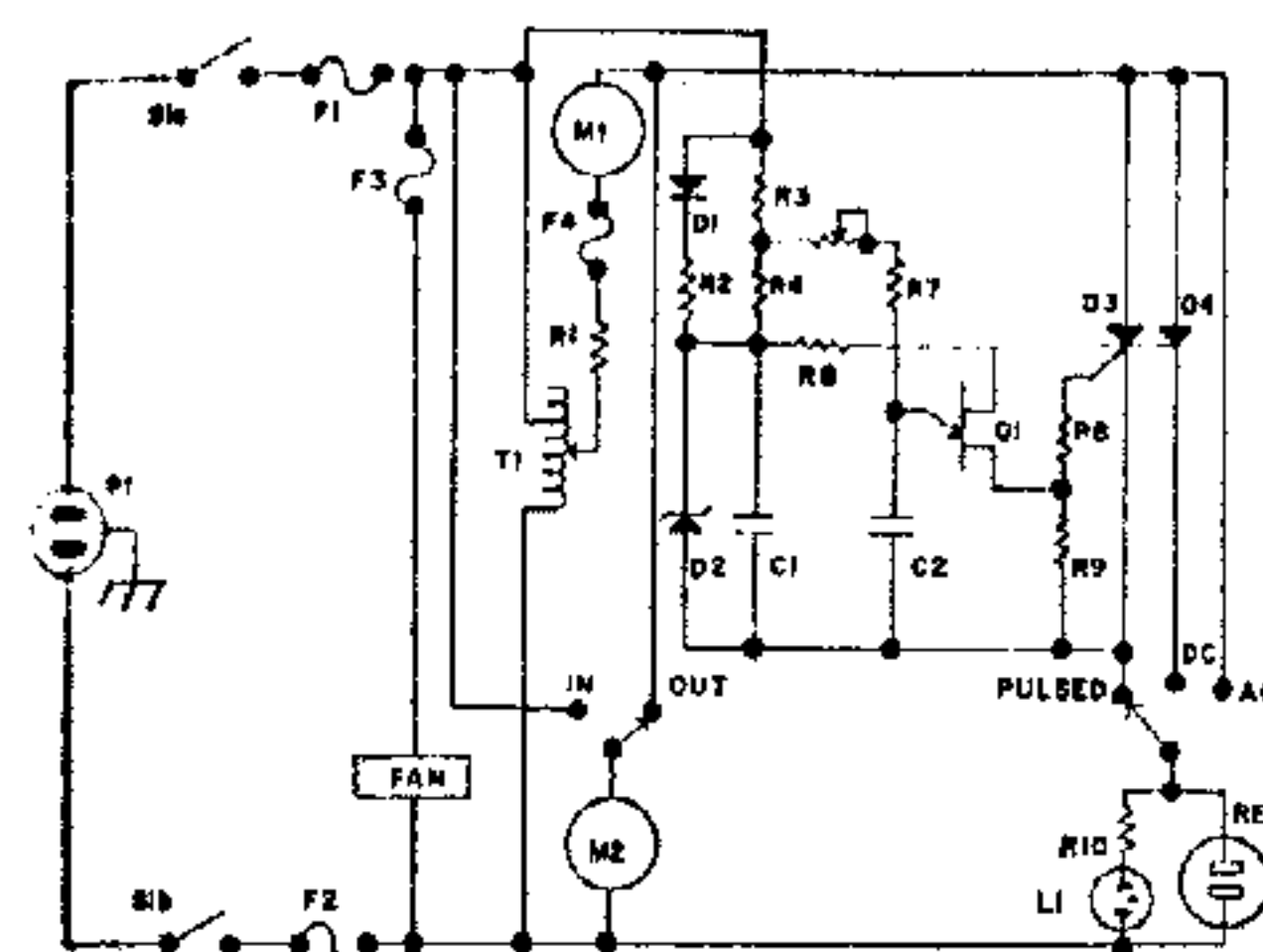


FIGURE 1.—Circuit description for variable voltage pulsator for electrofishing

- C1 250 mfd, 50 volt electrolytic capacitor
C2 .1 mfd, 50 volt mylar capacitor
D1 400 volt 1 amp diode (1N2070)
D2 Silicon power regulator, 10 watt, 20 volt, mounted in heat sink. (1N1820)
D3 Thyristor, 16A, 300 V. (2N687), mounted in heat sink.
D4 Silicon power diode 35A, 300 V (1N1187) mounted in heat sink.
F1 10A fuse
F2 10A fuse
F3 1A fuse
F4 5A fuse
L1 Neon Lamp
M1 15 amp alternating current meter
M2 150 volt alternating current volt meter
P1 Three wire line cord and 3 prong AC plug.
Q1 Unijunction transistor (2N1671B)
R1 2 ohm 800 watt (4 each 2 ohm 200 watt resistors connected in a parallel series arrangement) mounted so air from the fan circulates over them.
R2 1000 ohms 10 watt wire wound resistor
R3 150 ohm 1/2 watt carbon 10% resistor
R4 10K ohm 1/2 watt carbon 10% resistor
R5 1 meg linear 2 watt variable resistor
R6 470 ohm 1/2 watt carbon 10% resistor
R7 100K ohm 1/2 watt carbon 10% resistor
R8 10 ohm 1/2 watt carbon 10% resistor
R9 100 ohm 1/2 watt carbon 10% resistor
R10 100K ohm 1/2 watt carbon 10% resistor
S1 double pole single throw 10 amp toggle switch
S2 single pole double throw 1 amp toggle switch
S3 single pole three position 10 amp selector switch
T1 10 amp variable autotransformer (Staco 2PF1010)

and the output voltage from the autotransformer can be monitored on the voltmeter (M2). The meter switch (S2) selects the desired voltage to be measured.

In the AC mode, the output from the autotransformer is applied directly to the electrodes by the function switch. Lamp (L1), electri-

cally in parallel with the electrodes, indicates the presence of power.

For DC operation only the positive half cycles are applied to the electrodes by the rectifying diode (D4) when the selector switch is in the DC position. This applies pulsating 60 cycle DC to the electrodes.

For pulsed DC operation the selector switch is placed in the pulsed mode and the thyristor or silicon controlled rectifier (D3) is connected to the electrodes. The thyristor is triggered by the unijunction transistor (UJT) oscillator (Q1). The DC supply voltage for the UJT oscillator is obtained from the half-wave rectifier (D1) and filter capacitor (C1). The zener diode (D2) regulates the voltage at 20 volts with R2 limiting the current to a safe value. The frequency of oscillation is determined by the timing capacitor (C2) and the combined resistance of R5 and current limiting resistor R7. R6 is a current limiting resistor for the UJT. When Q1 conducts, C2 is discharged through limiting resistor R9 causing a positive voltage at the junction of current limiting resistor (R8) and R9 which turns on D3.

The oscillation frequency can be adjusted for firing at 15, 30, or 60 cycles per second. Resistor R3 couples enough AC signal to assure easy synchrony with the line voltage making it possible to vary the DC pulse width as well as frequency of output.

Our circuit is similar to that described by Moore (1967) but offers the following advantages: (1) heavier duty, (2) three modes of operation, (3) variable voltage.

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LITERATURE CITED

- LAGLER, K. F. 1968. Capture, sampling, and examination of fishes, p. 7-45. In W. E. Ricker (ed.), *Methods of assessment of fish production in freshwaters*. Wilmer Brothers Limited, Birkenhead.
- MOORE, W. H. 1968. A lightweight pulsed D. C. fish shocker. *J. Appl. Ecol.* 5: 205-208.
- STUBBS, J. M. 1966. Electrofishing using a boat as the negative. *Proc. 19th Annu. Conf. Southeast. Ass. Game Fish Comm.* (mimeo).